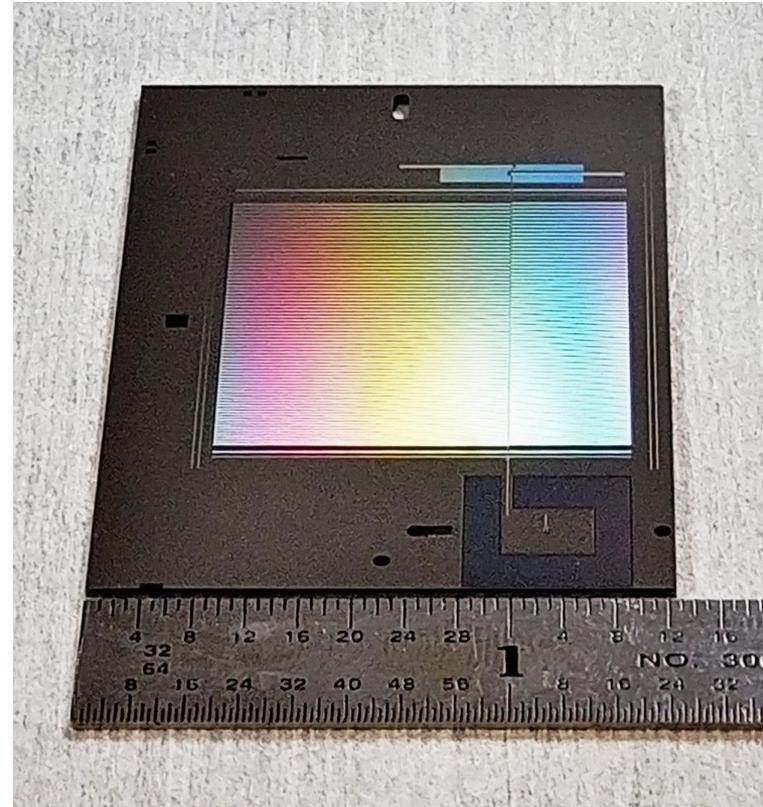
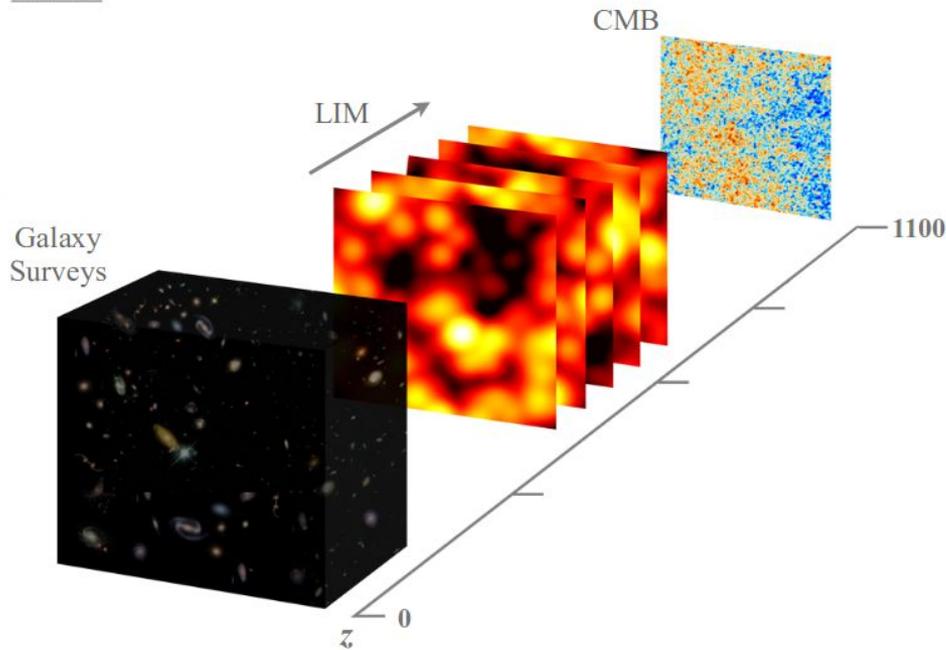


# Pushing the Limits of Cosmology with Millimeter-Wave Spectrometers

Probes:



Kirit S. Karkare  
NSF/Schramm Fellow @ University of Chicago/Fermilab  
CPAD, 2021-03-22

# Outstanding Questions in Cosmology

Did **inflation** set the initial conditions that we see in the CMB?

What is the **dark matter**?

What is the **dark energy** causing the present-day acceleration?

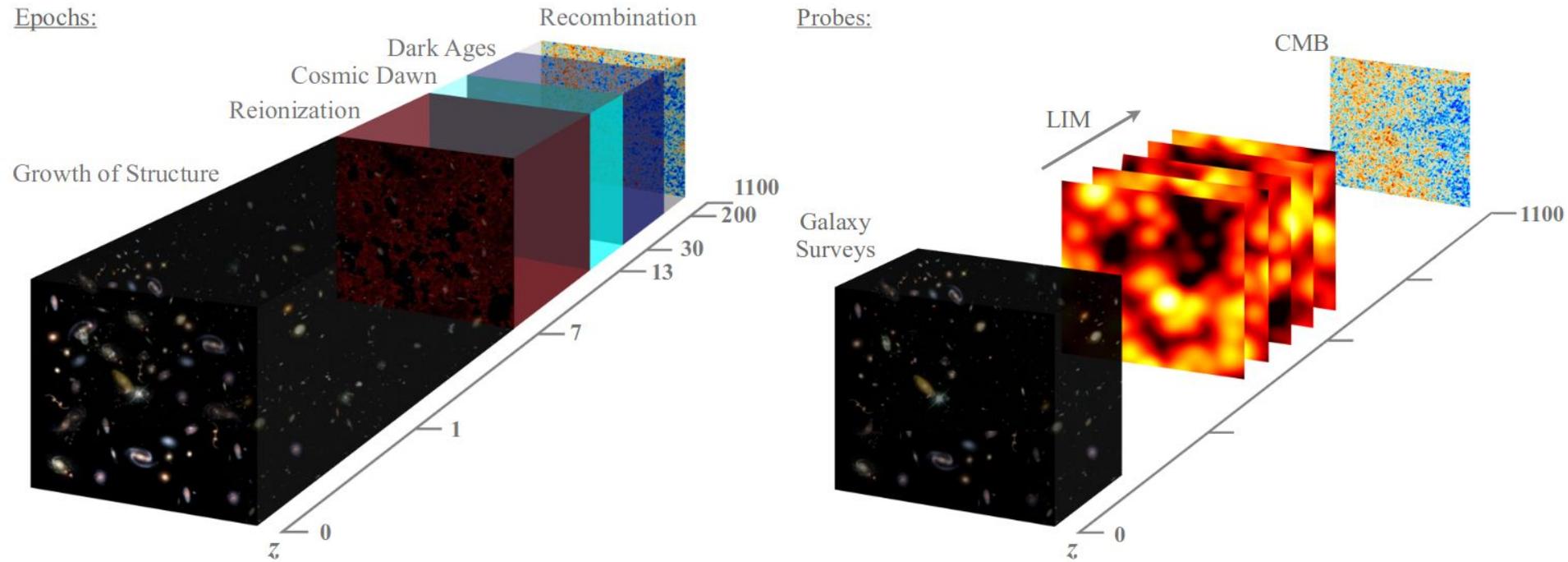
Tensions, e.g. Hubble constant

Progress can be made by extending large-scale structure measurements to *higher redshift (distance)*

→ more volume (higher precision)

→ earlier times (probe different cosmological epochs)

# Observables of Large-Scale Structure

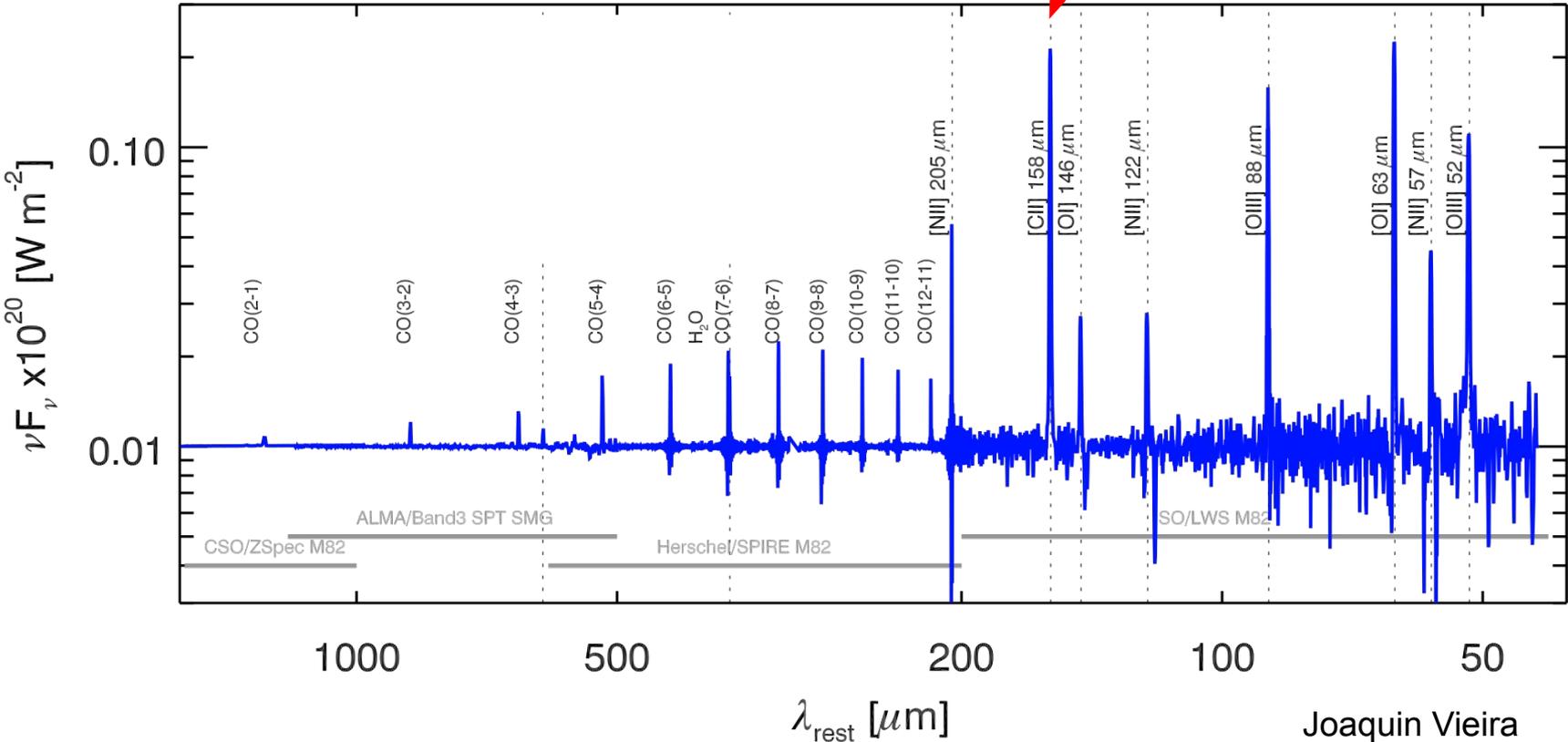


**“Line Intensity Mapping” (LIM):** using low angular resolution observations of a spectral line to map a 3D volume (wavelength  $\rightarrow$  redshift), *without resolving individual sources*.

# Use a mm-wave spectrometer to identify redshift

Spectrum of a star-forming galaxy  
(continuum emission removed)

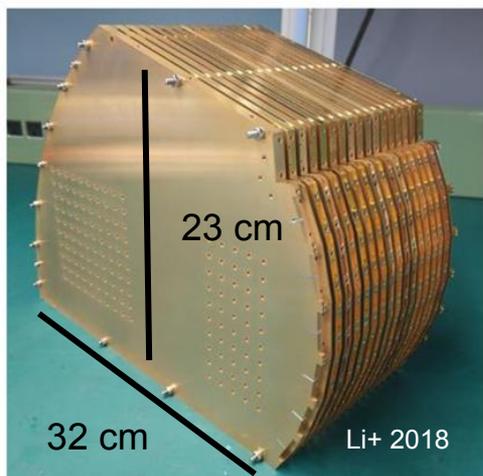
Ionized carbon  
fine-structure line  
[CII], C+



# On-Chip Spectroscopy Enables Large Arrays

Space inside the telescope is at a premium.

Instead of using a diffraction grating (or Fabry-Perot or Fourier Transform Spectrometer), print a spectrometer on a silicon wafer.



Compare one spectrometer:

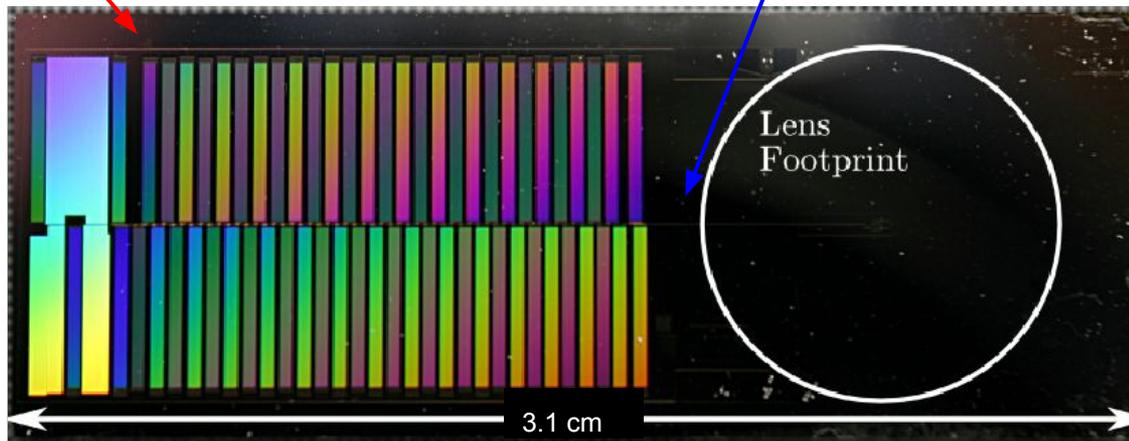
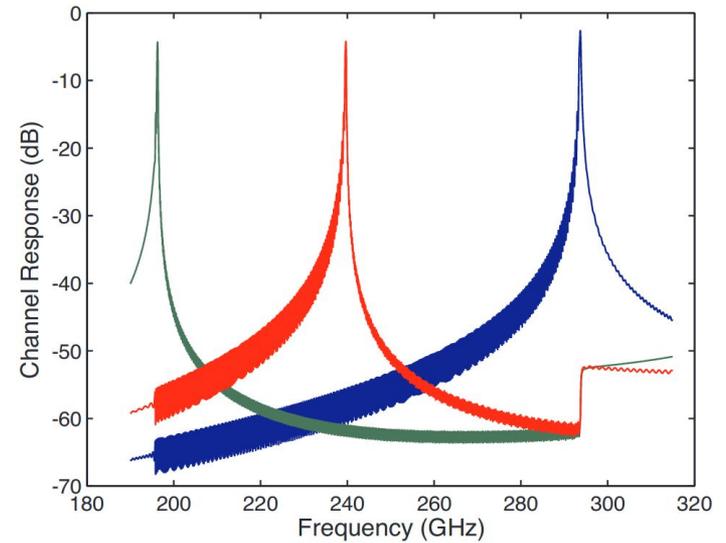
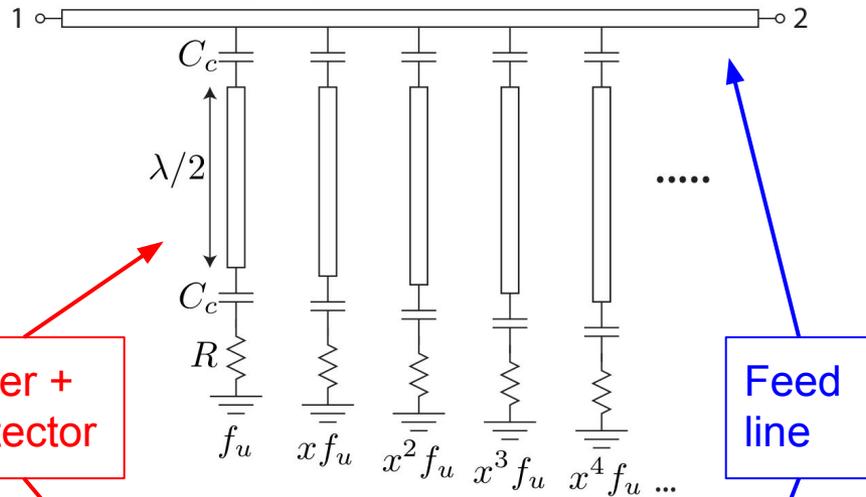
TIME grating  
32 x 23 x 1 cm ~ **736 cm<sup>3</sup>**

SuperSpec  
3.6 x 5.7 x 0.05 cm ~ **1 cm<sup>3</sup>**



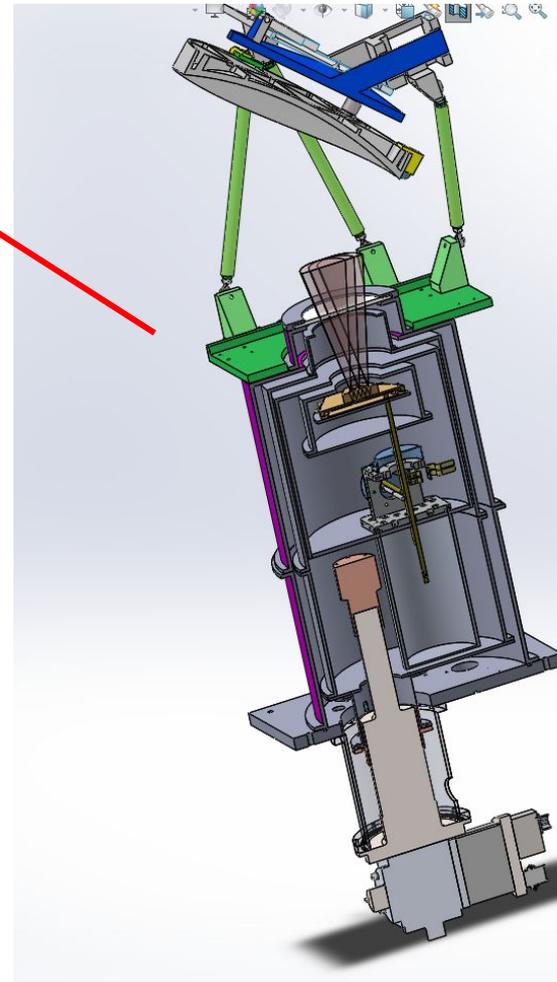
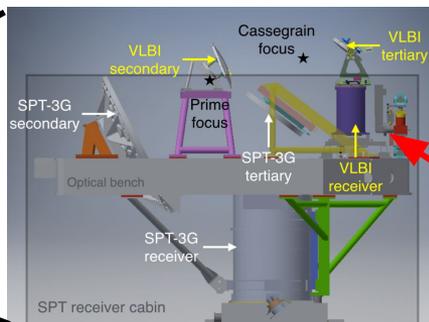
Could pack orders of magnitude more spectrometers in a given volume!

# SuperSpec: A Filter-Bank Spectrometer Printed on Silicon



Kovacs & Zmuidzinas 2010

# SPT-SLIM: the South Pole Telescope Summertime Line Intensity Mapper



Just funded through Fermilab LDRD!

**LIM pathfinder** using on-chip spectrometers

Observe in 2022/2023 Austral summer  
season (SPT-3G remains in place)

Anticipate  $5\sigma$  detection of LIM signal

# Summary

Millimeter-wave line intensity mapping detects galaxies through far-IR emission lines, and will probe inflation, dark matter, and dark energy beyond the redshift reach of traditional galaxy surveys.

On-chip spectrometers will enable filled focal planes with orders of magnitude more detectors than current instruments.

SPT-SLIM will demonstrate LIM with on-chip spectrometers in 2 years!

